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TITLE- Apollo Command System - Spacecraft Computer Update Delays Using the Updata Link.

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DATE-March 28, 1969

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AUTHOR(S)- J. E. Johnson

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Command Module Computer
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ABSTRACT

The time required for the Mission Control Center to update the Command Module Computer or Lunar Module Guidance Computer using the updata link is examined. It is shown that for a spacecraft at lunar distance slightly more than one minute is required for a typical update, such as a state vector update, assuming normal system operation. Figures are presented showing expected delays as a function of distance and of length of the computer update. The additional delay to be expected due to retransmission of words with detected errors is discussed.

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BELLCOMM, INC.
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SUBJECT: Apollo Command System - Spacecraft Computer Update Delays Using the Updata Link - Case 900

DATE: March 28, 1969

FROM: J. E. Johnson

T.M. 69-2034-3

TECHNICAL MEMORANDUM

Concern has sometimes been expressed about the delays inherent in the Apollo command system. In particular, it has been thought that the time required to update the Command Module Computer (CMC)* or Lunar Module Guidance Computer (LGC) at lunar distance via the updata link could be excessive. The delays in the system are the result of the system design, message coding, and operational procedures. This memorandum examines the delays that could be expected in updating the CMC or LGC, based upon the command system hardware, software, and operational procedures used for Apollo missions AS-205 and subsequent (Universal Command System). It is shown that the maximum length update (18 computer words) to a spacecraft at lunar distance, assuming normal system operation, will require about 80 seconds. This does not appear to be excessive when considered in the context of the operational environment.

TYPES OF UPDATES

There are four basic types of updates to be used with the updata link to the CMC and LGC. Two of these, Verb 71-type updates and Verb 72-type updates, are used to alter data or instructions stored in the computer's erasable memory. The Verb 71 update is used to alter the contents of up to 18 consecutive spacecraft computer memory registers (15 bits each). The Verb 72 update is used to alter the contents of up to 9 non-consecutive memory registers. Longer length updates can be used; in this case the total update is broken up into blocks of not more than 18 (9) CMC/LGC words each, and each block is uplinked and verified as if it were a complete update in itself. All pre-mission identified and labeled updates (e.g., state vector updates, target updates) are contained in not more than 18 computer words and can be uplinked as an entity. There does exist a capability, however, to alter the contents of any part or all of the erasable memory in both spacecraft computers. The

*A list of abbreviations and acronyms used in this memorandum is given on page 12.

other two updates, Verb 70 and Verb 73, are time increment updates. Verb 70 is a lift-off time update, transmitted in double precision (2 computer words, or 30 bits). Verb 73 is a clock time update, also transmitted as a two-word double precision parameter.

The Verb 71 uplink format is as follows:

V71E	Verb Preamble	
IIE	Index ($3 \leq II \leq 20$)	
AAAAE	Starting Address	
XXXXXE		
XXXXXE		Stored in "UPBUFF"
.	Data (up to 18 lines)	
.		
.		
XXXXXE		
V33E	Final Enter	

The Verb Preamble tells the computer the format of the data to follow. The Index gives the number of lines (words) to expect, including the index line. The Starting Address is the erasable memory address at which the computer is to start loading the data after it has been verified. Up to 18 lines of data follow. Each line consists of 5 octal digits, comprising a 15-bit CMC or LGC word. The Index, Starting Address, and data are all stored in consecutive slots in buffer storage (UPBUFF) until the ground verifies via telemetry that they were received correctly. After ground verification, a "Final Enter" code is transmitted, causing the data to be transferred from UPBUFF to the desired locations as indicated by the starting address. Each line of instruction and data must be terminated with an "Enter" (E) character; although, only the 4-character "Final Enter" (V33E) code will cause the data to be entered into working memory. These Enters are not stored in the spacecraft computer. The Final Enter is transmitted only after the ground has verified correct receipt of all the data.

Each uplinked character (octal digit, V, E, etc.) is formatted as a 5-bit "keycode", and is uplinked in true-complement-true form. Accompanying each keycode is a 3-bit vehicle address, a 3-bit system address, and a logical "one". Each bit is sub-bit encoded at the transmitting site, a process that substitutes a 5-bit code for each information bit.

Thus 110 sub-bits (22 information bits) are uplinked for each character. This keycode format is shown in Fig. 1. A list of keycodes and their bit structures is given in Table 1.

The Verb 72 uplink format is as follows:

V72E	Verb Preamble		
IIE	Index ($3 \leq II \leq 19$)		
AAAAE	Address for first line		
XXXXXE	First line of data		
AAAAE	Address for second line	Addresses and Data (up to 9 pairs)	
XXXXXE	Second line of data		Stored in "UPBUFF"
.			
.			
.			
AAAAE	Address for last line		
XXXXXE	Last line of data		
V33E	Final Enter		

This update differs from the Verb-71 update in that data is not required to be stored in consecutive memory registers. Since an address must be supplied with each line of data, the length of the update is limited to 9 lines of data. This constraint is due to the "UPBUFF" total capacity of 20 lines. As with the Verb 71 update, the index, addresses, and data are all stored in UPBUFF until verified by telemetry read-out. The Final Enter causes each line of data to be transferred to its indicated address in working memory.

The same 110 sub-bit uplink format is used as for the Verb 71 update.

The verb 70 uplink format is as follows:

V70E	Verb Preamble	
XXXXXE	Most Significant Part of Time Increment	Stored in "UPBUFF"
XXXXXE	Least Significant Part of Time Increment	
V33E	Final Enter	

The Verb 73 format is identical except for the substitution of V73E for V70E. Verification procedures are the same as for Verb 71 and Verb 72 updates. Verb 70 and Verb 73 updates will not be considered further in this memorandum.

A list of command loads is given in Table 2. The Erasable Memory updates are general updates, and may be any length. All others are contained in not more than 18 lines (Verb 71) or 9 lines (Verb 72).

COMMAND OPERATIONAL PROCEDURES

Command updates (loads) are normally generated considerably in advance of the time they are expected to be used. The update, less the Final Enter, is transmitted in keycode format to the selected MSFN site(s) and stored in the memory of the Remote Site Command Computer (RSCC). The actual uplinking of the load is under the control of flight controllers at the Mission Control Center (MCC) in Houston.

The normal commanding procedures are the following:

1. The command load is generated by the Real-Time Computer Complex (RTCC) at the MCC under instructions from a flight controller and transmitted to a remote site, where it is stored in the memory of the RSCC. It is assigned a unique load number.

2. If it is desired to uplink the load the crew is asked to place the computer in the "Idle" (Program 00) mode, and to insure that the UP TLM switch is in the "ACCEPT" position.

3. The flight controller will transmit the load number to the site along with a "Verb Initiate" request. The RSCC will then uplink the 3 characters "V71" or "V72" associated with that load. Correct receipt of these 3 characters is verified by observing a display of telemetered data on the flight controller's console.

4. Upon verification of the "V71" or "V72", the flight controller will transmit a request to the site to uplink an Enter ("E"). This will also be verified by visual observation of telemetry data.

5. The actual load will be called up by transmitting a "Load Initiate" request to the RSCC. The RSCC will remove the load from memory, format it into the 22-bit uplink format, sub-bit encode it, and uplink it

at a rate of one keycode character (octal digit) every 160 ms. The load will be verified by having the RSCC perform a bit-by-bit comparison of the telemetered read-out of the UPBUFF contents with what it has stored in its memory. A verification message will be sent to the flight controller at the control center.

6. Upon verification of the load, the flight controller will transmit a request for the "V" of the Final Enter, and await visual verification before proceeding.

7. The same procedure will be followed for the first "3".

8. Ditto for the second "3".

9. The "E" for the Final Enter will be transmitted after verification of the second "3", and will cause the update to be transferred from UPBUFF to the indicated address(es) in working memory. The crew will normally return the up TLM switch to "BLOCK" following completion of the update.

These steps are summarized below:

Part of Command	Verification
V71 or V72	Visual - MCC
E	Visual - MCC
Index, Address and data	Automatic - RSCC, with message sent to MCC
V	Visual - MCC
3	Visual - MCC
3	Visual - MCC
E	--

Flight controller action is necessary to initiate each of these steps. Thus, human response time is a component of command delay.

COMMAND LOADING DELAYS

Since a command load is normally generated and transmitted to a remote site in advance of its use, the delays associated with these processes do not normally enter into the overall commanding delay. For those relatively rare cases when it is desired to generate a load and uplink it immediately, an estimate of the load generation time is in the neighborhood of 15 seconds, and the load transfer time to the remote site is about 3.5 seconds. Making an allowance for flight controller response time to the remote site acknowledgement of correct acceptance of the load (validation), perhaps 20 seconds would be required prior to the commencement of the uplinking process.

The load generation time includes the time required for the flight controller to verbally instruct the RTCC Computer Command Controller (CCC) as to the nature of the load he wants, the time for the CCC to input the necessary data to the RTCC, the RTCC load generation time, the time required for read-out and display generation of the load to the CCC and to the requesting flight controller, the time taken to visually review the load, and the time to transfer the approved load to the Communications, Command and Telemetry System (CCATS). Gemini experience has shown that command load generation requires about 12-15 seconds. These processes are essentially the same for Gemini and Apollo, and the times should be comparable.

The transmission and validation time required for an 18-word update is itemized under the "Command Loading" heading, item I in Table 3, and is shown to be about 3.5 seconds. This assumes normal system operation, with no errors detected and no retransmissions. The transmission path is assumed to consist of a 50.0 kbps Wide Band Data (WBD) circuit between Houston and Goddard, and a 2.4 kbps High Speed Data (HSD) circuit between Goddard and the remote site routed via a communications satellite at synchronous altitude. All times are approximate. Processing delays are particularly hard to predict, since they depend upon what else may be going on inside the computer when the data arrives, and what priorities are associated with the various tasks it is called upon to perform. The times listed in Table 1 are estimates of the maximum (or in some cases near-maximum) delays to be expected assuming normal operation, and no overloading of the system. The estimates were based on information from Ref. 1, and from discussions with MSC personnel.

Details of the command loading, uplinking, and verification processes are given in Ref. 2.

COMMAND UPLINKING DELAYS

There are seven steps in the uplinking of a CMC or LGC update (as listed on page 16). The items contributing to delays in these steps are tabulated under Sections II-VIII in Table 3.

Each step is initiated by an Execute Command Request (ECR) transmitted from the Control Center to the RSCC. The ECR is generated in CCATS in response to pushbutton signals from the flight controller's console. The transmission path to the remote site is the same as for the load data.

The first step of the uplink sequence is the uplinking of "V71" or "V72". The ECR for this step contains the load number, the code for "Verb-Initiate", and an indication of whether UHF or USB transmission is to be used (determined by the flight controller). The delays to be expected for the transmission and verification of this step total about 8 seconds, and are itemized in Section II of Table 3. It is assumed the spacecraft is at lunar apogee (2.2×10^5 nm). The uplink rate is 1 kbps. There is a 50 ms spacing between the uplinking of successive characters to permit the spacecraft decoder to clear out the previous character. The rate of uplinking is thus one character (110 sub-bits) per 160 ms.

The Verb Preamble is telemetered back to the ground as part of a 200 word (15 bits/word) CMC or LGC read-out list. When operating in the high-bit rate telemetry mode (51.2 kbps), this list will be read out every two seconds. However, the information to be verified appears twice in the list, separated by 99 words. Thus the maximum wait will be one second. When operating in the low-bit rate mode from the CSM (1.6 kbps), the list is read out every 10 seconds, and the maximum wait is 5 seconds. The list does not appear in the LM low bit rate telemetry. It is not planned as a normal procedure to command when operating in the low rate mode. Hence, one second was taken as the applicable maximum delay for this study. The average delay would be one-half second, and the minimum would be zero, depending on where in the read-out cycle the telemetry system happened to be when the data was received.

The second step, uplinking an Enter to condition the computer for the data to follow (instructing it to go to Program 27), requires essentially the same time as the first. The only difference is that since only one keycode is required, 320 ms are saved. The total for this step is thus about 7.5 seconds. However, before this step (and all succeeding steps) can begin, the flight controller must observe the verification signal he receives from the preceding step, and respond with the appropriate manual actions (pushbutton depressions). Since he would logically be expected to be giving his full attention to this activity, his reaction time should be short (although long relative to computer processing times). A figure of two seconds was arbitrarily assumed for this study. It should be noted that an inattentive flight controller could significantly increase the total system delay.

The uplinking of the load data (Section IV of Table 3) would take about 26.5 seconds for a maximum length of 18 words. This step is initiated by an ECR giving the load number. This causes the load to be removed from RSCC storage, formatted, and uplinked as an entity. There is no wait for verification until the entire load has been uplinked. Since each word consists of 5 octal digits plus an enter, it requires 960 ms to uplink a word. Thus, for loads of shorter length, approximately one second should be subtracted for each word less than 18.

Verification of the load data is performed automatically by the RSCC using telemetry data in what is termed a "buffer compare" routine. The data received by the spacecraft computer (but not the Verb Preamble or Final Enter) is stored temporarily in UPBUFF. The contents of UPBUFF are part of the 200 word read-out list referred to earlier, and are read-out twice every two seconds. These read-outs are compared by the RSCC with the data that it uplinked. Two successful comparisons are required to establish verification, thus requiring two seconds maximum (one second minimum) of telemetry delay. Should the verification fail, the RSCC is programmed to note the words failing, and look at up to 6 additional telemetered readouts in an attempt to establish verification on these words. When verification is established, a message is sent to the MCC and routed to the flight controller initiating the command. Should verification not be established, the identity of the lines (words) not verified will be provided. This situation will be discussed in the section on delays due to non-nominal conditions. The message, a CAP VER (Command Analysis Pattern Verification), is sent as part of the telemetry bit stream being returned to the MCC. It is sent three times in three consecutive one-second long telemetry data frames. On missions with two spacecraft, there will be two HSD lines for telemetry, and the CAP VER's will be sent twice on one line and once on the other, phased one-half second apart.

Following flight controller recognition that UPBUFF contains the desired data, the "Final Enter" sequence is initiated. This consists of four keycodes sent one at a time. The time required for transmission and verification of each of the first three keycodes "V", "3", and "3" will be about 7.5 sec., as before. After verification of the "V33", the Enter keycode is transmitted to release the data to computer working memory. Since verification is not applicable for this keycode, it will consume only a little more than two seconds.

The total delay for entering an 18-word update into CMC or LGC working memory at lunar distance is thus estimated to be about 67 sec., plus the time for 6 operator responses. With a two sec. estimate for each of the latter, the over-all time becomes 79 sec. If it is also required to consider the load generation time in the RTCC, about 20 sec. would be added, for a total of about 100 seconds. In this latter case, the flight controller decision-making time preparatory to starting load generation and the time required to specify the input parameters would also have to be considered, and could be expected to be significant. Figure 2 shows the components of the total update delay.

Figures 3 and 4 show the over-all delays to be expected for Verb 71 updates and Verb 72 updates, respectively, as functions of load length and slant range.

NON-NOMINAL CONSIDERATIONS

If verification is not established on the keycodes associated with the Verb Preamble or the Final Enter, the normal procedure is to repeat the transmission until verification is achieved, or until the flight controller decides that further attempts are futile. Each keycode retransmission could be expected to take about 7.5 seconds, plus operator response time.

If verification is not established on the load data, a delay of 6 additional seconds is introduced before the buffer compare routine of the RSCC times-out. This is to allow for 6 additional UPBUFF read-outs in an attempt to achieve comparison. The lines failing to compare are identified to the flight controller via a CAP NON-COMPARE message in lieu of a CAP VER. The normal procedure would now be to initiate retransmission of the lines in error (line-by-line correction) if they do not exceed 3, and to clear the load and start over if they do. The additional delay to be expected for a line-by-line correction would be about 15 seconds for one line in error, and about 1.5 sec. extra for each additional line to be corrected, plus operator response time. This assumes that verification on the second uplinking attempt will occur on the first two readouts of the UPBUFF list. These times include the 6 extra seconds inherent in the buffer compare routine on the first uplink attempt. Each word to be uplinked in the second attempt must be accompanied by a two digit identifier to enable the computer to identify which word in UPBUFF is to be corrected. Thus, 9 keycodes are required per word to be corrected; as follows:

iiE	Identifier ($1 \leq ii \leq 20$)
xxxxxE	Corrected Data
iiE	.
xxxxxE	.
iiE	.
xxxxxE	.

If it is desired to clear the load and start anew, the procedure is to first send "V34E" (terminate) which will cause the spacecraft computer to discard all data it has stored in UPBUFF and return to the program it was in before the update was initiated. The entire uplink process is then reinitiated, starting with the Verb Preamble. In this case, the delay to be expected would be about 6 seconds extra waiting for the buffer compare routine to time out, plus another 80 seconds for a repeat of the entire uplink process, assuming everything goes perfectly the second time. The "V34E" used to terminate the first uplink attempt could be expected to consume about the identical time as the "V33E" would have. However, a longer operator delay time could logically be expected, as the operator must now choose among alternatives in dealing with a non-nominal situation.

SUMMARY AND CONCLUSIONS

Between one and one and one-half minutes could logically be expected to be consumed in a typical update to a spacecraft computer at lunar distance. The representative case developed in Table 3 used 79 seconds. Should corrections be required, they would consume perhaps 20-30 additional seconds on a line-by-line correction basis, or about as long again if the incorrect load is discarded and the entire load sequence reinitiated.

The time required for an update can only be judged to be excessive or not when viewed in an operational context. The nature of an update is such that it is rarely required immediately, and the consequences would not be likely to be catastrophic if the update were to be delayed for a few minutes.

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2034-JEJ-bjw

Attachments
- References
- Abbreviations and Acronyms
- Tables 1-3
- Figures 1-4

REFERENCES

1. Apollo Command - Telemetry Control Capabilities for Mission C and D, Philco-Ford Report PHO-TN227, June 28, 1968.

2. Apollo Command System - Ground Network Data Flow, Case 900, Bellcomm Technical Memorandum No. 68-2034-8, by J. E. Johnson, June 20, 1968.

3. Command Data Format Control Book, Data Acquisition Plan, Annex C, Revision 3; MSC, November 15, 1968.

ABBREVIATIONS AND ACRONYMS

CAP COMPARE	Command Analysis Pattern Comparison
CAP NON-COMPARE	" " " Non-comparison
CAP VAL	" " " Validation
CAP VER	" " " Verification
CCATS	Communications Command and Telemetry System
CMC	Command Module Computer
E	"Enter" Keycode
ECR	Execute Command Request
GSFC	Goddard Space Flight Center
HSD	High-Speed Date (2.4 kbps)
kbps	kilobits per second
LGC	Lunar Module Guidance Computer
MCC	Mission Control Center
mHz	megahertz (megacycles/second)
MOCR	Mission Operations Control Room (in MCC)
MSFN	Manned Space Flight Network
ms	millisecond
nm	nautical miles
RS	Remote Site
RSCC	Remote Site Command Computer
RSTC	" " Telemetry Computer
RTCC	Real-Time Computer Complex

ABBREVIATIONS AND ACRONYMS (Contd.)

SC	Spacecraft
TLM	Telemetry
UDB	Updata Buffer
UHF	Ultra-High Frequency
UPBUFF	Buffer Storage for data from MSFN in CMC or LGC
USB	Unified S-Band
V	"Verb" Keycode
W	Word (15 bits) in CMC or LGC
WBD	Wide-Band Data (50 kbps)

TABLE I

CMC/LGC KEYCODES

COMMAND DESCRIPTION	OCTAL	BIT STRUCTURE VA	SA	P	K	$\overline{K}$	K
LGC VERB (V)	31613504	011	001	1	10001	01110	10001
CMC VERB (V)	43613504	100	011	1	10001	01110	10001
LGC NOUN (N)	31770174	011	001	1	11111	00000	11111
CMC NOUN (N)	43770174	100	011	1	11111	00000	11111
LGC CLEAR	31760370	011	001	1	11110	00001	11110
CMC CLEAR	43760370	100	011	1	11110	00001	11110
LGC ENTER (E)	31740760	011	001	1	11100	00011	11100
CMC ENTER (E)	43740760	100	011	1	11100	00011	11100
LGC ZERO (0)	31603700	011	001	1	10000	01111	10000
CMC ZERO (0)	43603700	100	011	1	10000	01111	10000
LGC ONE (1)	31417404	011	001	1	00001	11110	00001
CMC ONE (1)	43417404	100	011	1	00001	11110	00001
LGC TWO (2)	31427210	011	001	1	00010	11101	00010
CMC TWO (2)	43427210	100	011	1	00010	11101	00010
LGC THREE (3)	31437014	011	001	1	00011	11100	00011
CMC THREE (3)	43437014	100	011	1	00011	11100	00011
LGC FOUR (4)	31446620	011	001	1	00100	11011	00100
CMC FOUR (4)	43446620	100	011	1	00100	11011	00100
LGC FIVE (5)	31456424	011	001	1	00101	11010	00101
CMC FIVE (5)	43456424	100	011	1	00101	11010	00101
LGC SIX (6)	31466230	011	001	1	00110	11001	00110
CMC SIX (6)	43466230	100	011	1	00110	11001	00110
LGC SEVEN (7)	31476034	011	001	1	00111	11000	00111
CMC SEVEN (7)	43476034	100	011	1	00111	11000	00111
LGC EIGHT (8)	31505640	011	001	1	01000	10111	01000
CMC EIGHT (8)	43505640	100	011	1	01000	10111	01000
LGC NINE (9)	31515444	011	001	1	01001	10110	01001
CMC NINE (9)	43515444	100	011	1	01001	10110	01001
LGC PLUS (+)	31721350	011	001	1	11010	00101	11010
CMC PLUS (+)	43721350	100	011	1	11010	00101	11010
LGC MINUS (-)	31731154	011	001	1	11011	00100	11011
CMC MINUS (-)	43731154	100	011	1	11011	00100	11011
LGC ALL ZERO*	31400000	011	001	1	00000	00000	00000
CMC ALL ZERO*	43400000	100	011	1	00000	00000	00000
LGC ERROR RESET	31623310	011	001	1	10010	01101	10010
CMC ERROR RESET	43623310	100	011	1	10010	01101	10010

*THIS COMMAND IS UNIQUE IN THAT THE KEYCODE COMPLEMENT IS NOT USED TO FORM THE UPLINK STRUCTURE AS IS THE CASE WITH ALL OTHER DSKY UPLINK STRUCTURES.

TABLE 2

LOAD DESCRIPTION/LOAD TYPES

UPDATE DESCRIPTION	VERB TYPE
CMC CSM NAVIGATION	71
CMC LANDING SITE VECTOR	71
CMC TIME INCREMENT	73
CMC LIFTOFF TIME	70
CMC LM NAVIGATION	71
CMC EXTERNAL ΔV	71
CMC REFSMMAT	71
CMC RETRO EXTERNAL ΔV	71
CMC ENTRY	71
CMC ERASABLE MEMORY A	71
CMC ERASABLE MEMORY A	72
CMC ERASABLE MEMORY B	71
CMC ERASABLE MEMORY B	72
LGC LM NAVIGATION	71
LGC CSM NAVIGATION	71
LGC EXTERNAL ΔV	72
LGC REFSMAT	71
LGC TIME INCREMENT	73
LGC LIFTOFF TIME	70
LGC LANDING SITE VECTOR	71
LGC DESCENT	72
LGC ERASABLE MEMORY A	71
LGC ERASABLE MEMORY A	72
LGC ERASABLE MEMORY B	71
LGC ERASABLE MEMORY B	72

TABLE 3

COMPONENTS OF DELAY

		Time Required (ms)
I.	COMMAND LOADING	
1.	CCATS processing	56
2.	MCC-GSFC transfer via WBD	23
3.	GSFC read in - 2400 bits @ 50 kbps	48
4.	GSFC processing	13
5.	GSFC-RS transfer via HSD using satellite at synchronous altitude	300
6.	RSCC read-in - 1722 bits @ 2.4 kbps	719
7.	RSCC processing for CAP VAL	980
8.	RSTC processing and buffering	800
9.	RS-GSFC transfer via HSD	300
10.	GSFC read-in - 480 bits @ 2.4 kbps	200
11.	GSFC processing	32
12.	GSFC-MCC transfer via WBD	23
13.	CCATS read-in - 600 bits @ kbps	12
14.	CCATS processing	21
		3527
II.	COMMAND UPLINKING - "V71" or "V72"	
15.	CCATS processing for ECR	56
16.	MCC-GSFC transfer via WBD	23
17.	GSFC read-in-600 bits @ 50 kbps	12
18.	GSFC processing	13
19.	GSFC-RS transfer via HSD	300

TABLE 3

COMPONENTS OF DELAY (Contd.)

		Time Required (ms)
20.	RSCC read-in - 102 bits @ 2.4 kbps	43
21.	RSCC processing	130
22.	UDB processing	30
23.	RS-SC propagation delay at lunar distance	1360
24.	SC read-in - 3 keycodes @ 160 ms, less 50 ms.	430
25.	CMC/LGC processing	180
26.	CMC/LGC telemetry waiting time - 1 readout	1000
27.	SC-RS propagation delay	1360
28.	RSTC processing and buffering	1300
29.	(Repeat of 9-14 above)	588
30.	MOCR display updating	1000
III.	"ENTER"	
31.	Operator response time	x
32.	(Repeat of 15-23 above)	1967
33.	SC read-in - 1 keycode	110
34.	(Repeat of 25-30 above)	5428
		7505+x

TABLE 3

COMPONENTS OF DELAY (Contd.)

		Time Required (ms)
IV.	LOAD DATA, W = 18	
35.	Operator response time	x
36.	(Repeat of 15-23 above)	1967
37.	SC read-in - 116 keycodes @ 160 ms, less 50 ms	18510
38.	CMC/LGC processing	180
39.	CMC/LGC telemetry waiting time - 2 readouts	2000
40.	SC-RS propagation delay	1360
41.	RSCC processing - buffer compare routine	1000
42.	RSTC processing and buffering - CAP COMPARE	800
43.	(Repeat of 9-14 above)	588
		26405+x
V.	"V"	
44.	Operator response time	x
45.	(Repeat of 32-34 above)	7505
		7505+x
VI.	"3"	
46.	Operator response time	x
47.	(Repeat of 32-34 above)	7505
		7505+x

TABLE 3

COMPONENTS OF DELAY (Contd.)

		Time Required (ms)
VII.	"3"	
48.	Operator response time	x
49.	(Repeat of 32-34 above)	7505
		7505+x
VIII.	"ENTER"	
50.	Operator response time	x
51.	(Repeat of 32-33 above)	2077
52.	CMC/LGC processing	180
		2257+x
	Total for uplinking	66507+6x ms
		$\approx$ 67+6x sec.
	For x = 2 sec.	= 79 sec.

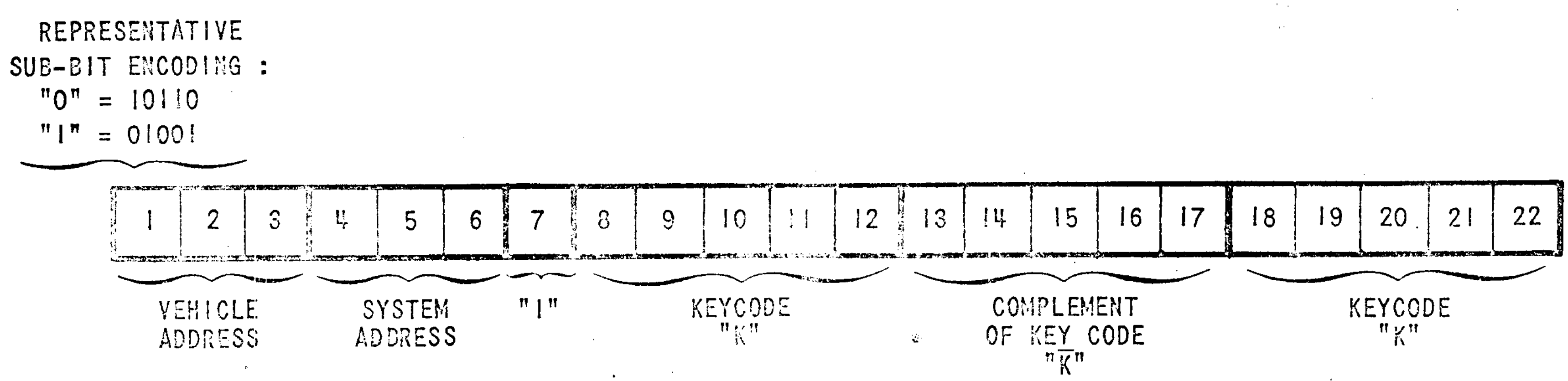

FIGURE 1 - KEYCODE UPLINK FORMAT

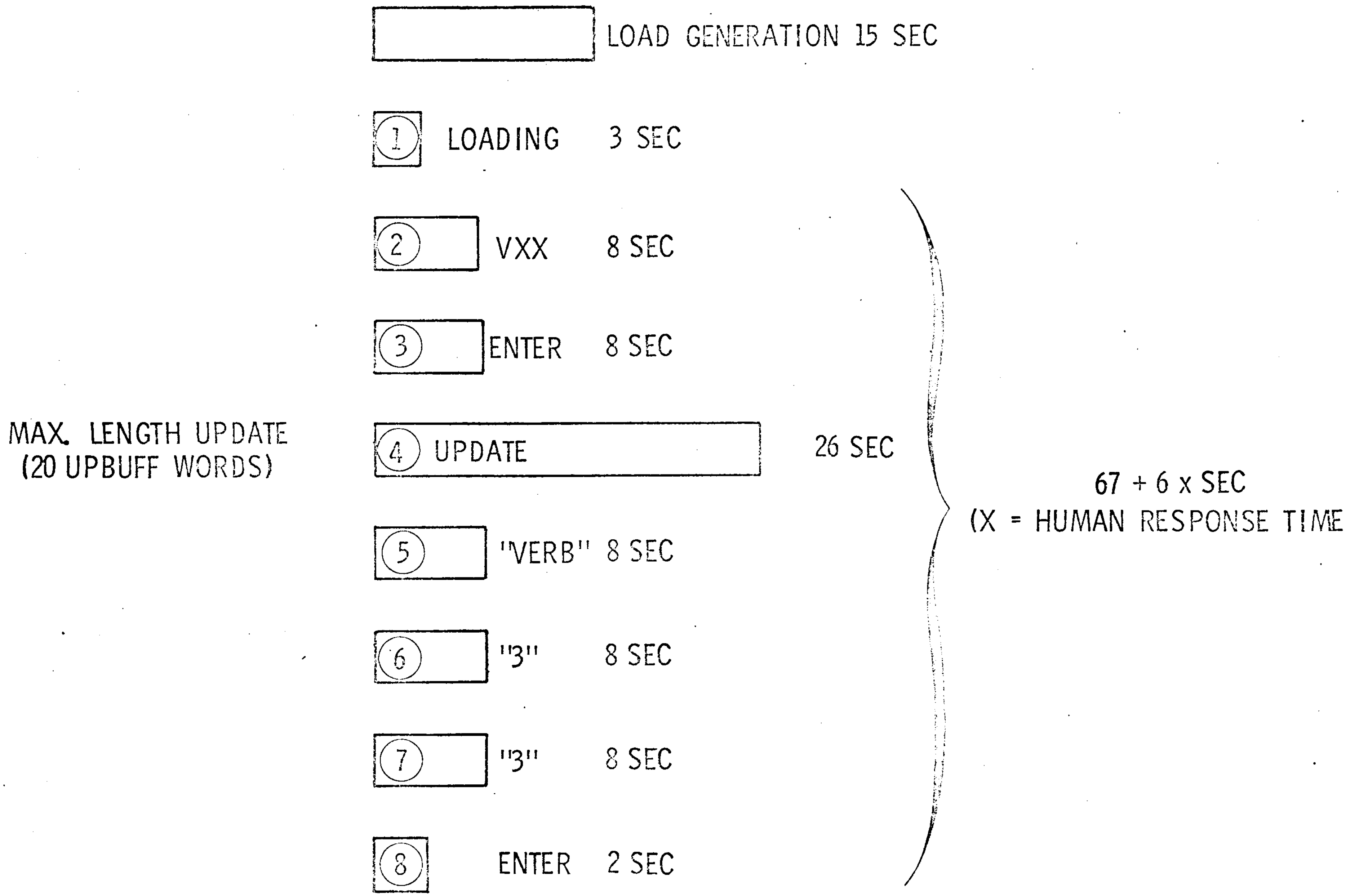

FIGURE 2 - COMMAND DELAYS AT LUNAR DISTANCE
(NOMINAL - NO RETRANSMISSION)

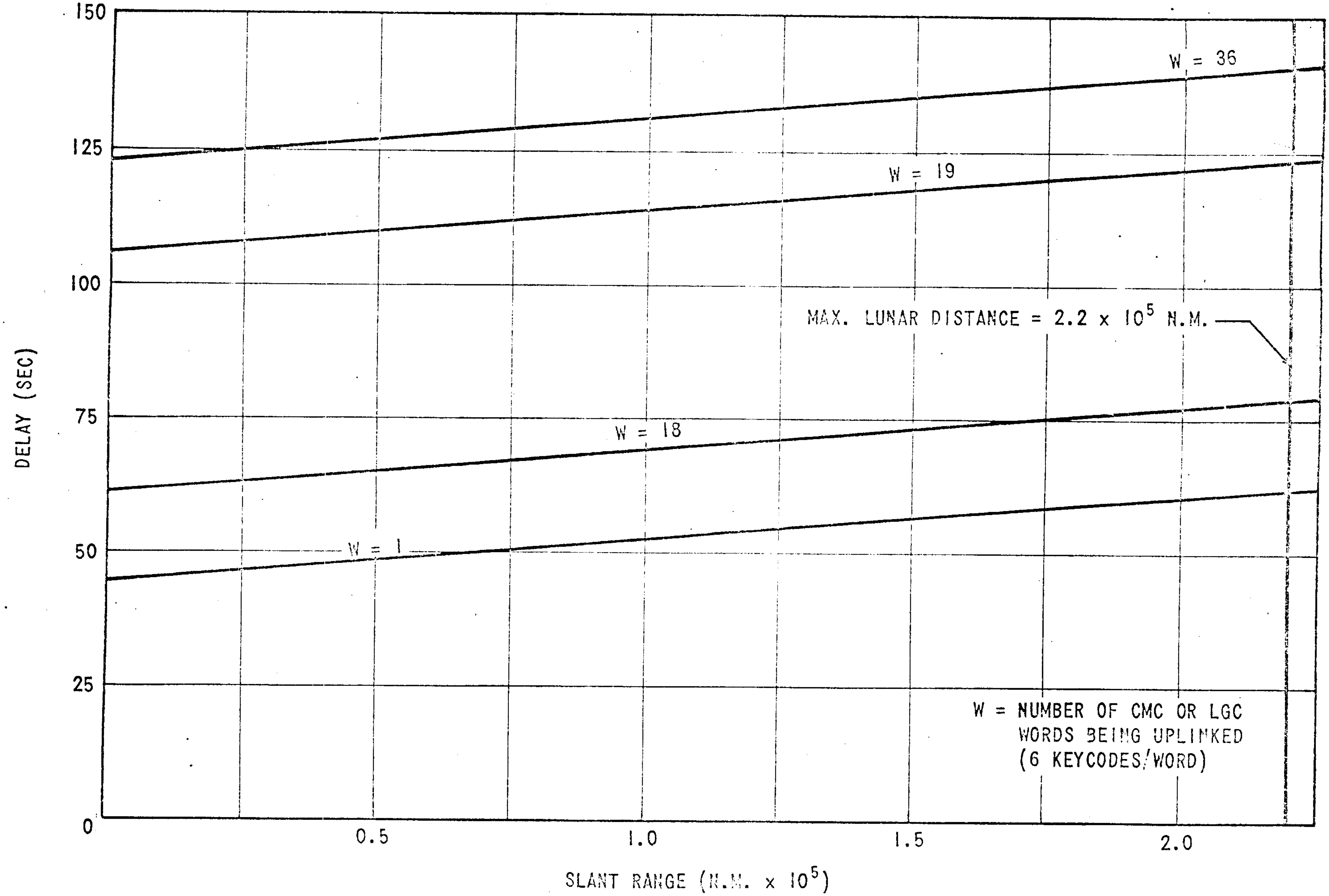

FIGURE 3 - DELAYS FOR VERB 71 UPDATES (NOMINAL - NO RETRANSMISSIONS)

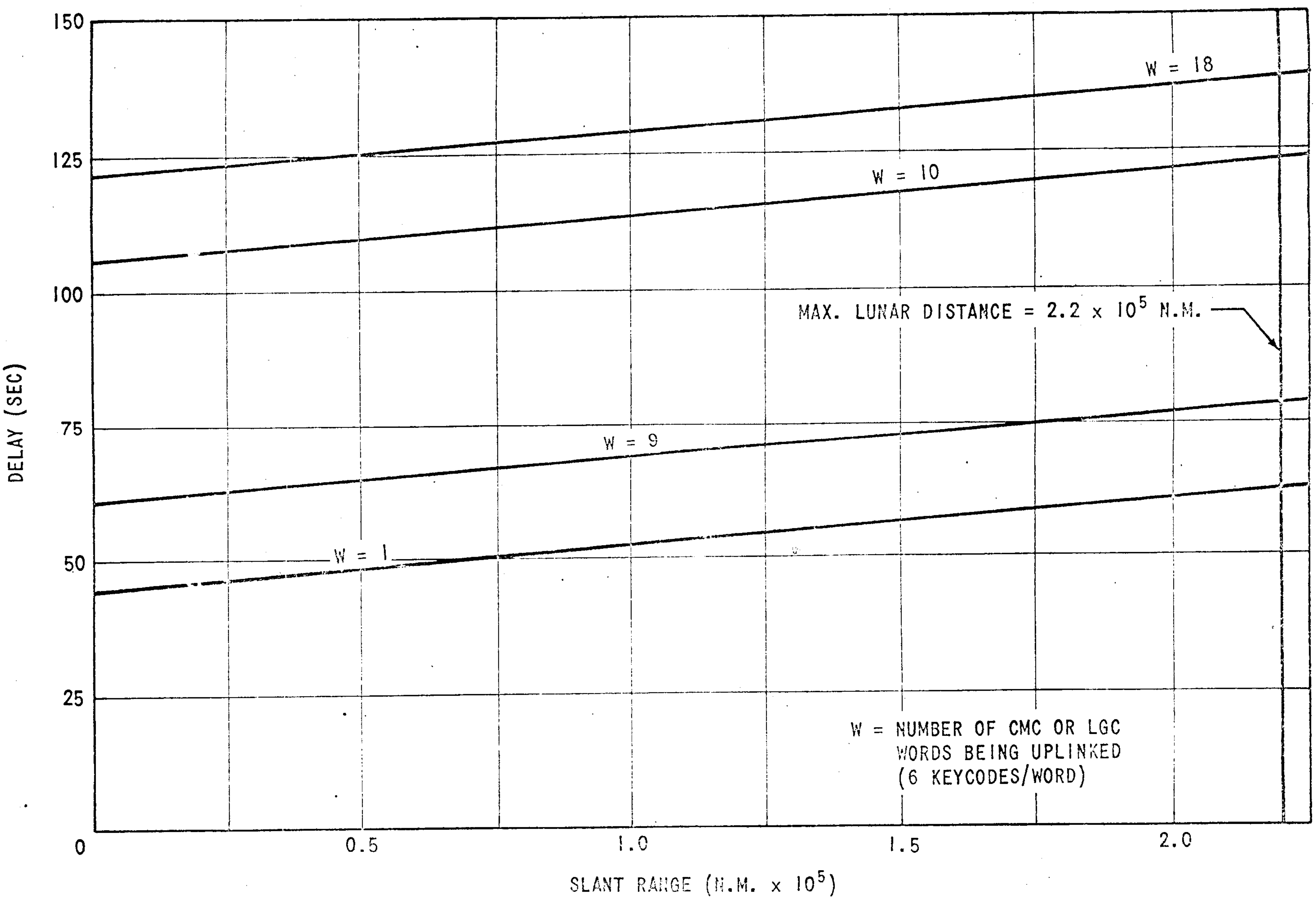

FIGURE 4 - DELAYS FOR VERB 72 UPDATES (NOMINAL - NO RETRANSMISSIONS)